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Communicating climate science: Components of engaging the agricultural audience

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Keywords
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Communicating Climate Science: Components of Engaging the Agricultural Audience

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ABSTRACT: The agricultural sector relies on climate information to formulate management decisions which hedge against environmental risks. How this scientific information is communicated by climatologists to the agricultural audience is investigated. It is necessary to not only provide data, but also frame the message as relevant to agriculture, encompassing risk management.

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1. INTRODUCTION

Agricultural producers must make a series of management decisions in response to uncertain risks arising from changes in the physical environment as well as shifts in the social, economic, and political conditions that affect the productivity and efficiency of agricultural production (Hardaker, 2004; Slovic, 2000). It is therefore important when considering the development of agriculture management actions to understand both changing external conditions and producer responses to these conditions. Of particular interest over the past decade has been understanding how climate science information is communicated to public data users, such as farmers and other stakeholders in the agricultural sector.

As individuals designated to interpret and translate weather and climate information for the constituents of their region, state climatologists have a unique position to communicate between regional and federal climate centers and public climate data users, such as producers of grain crops. The structure of a state climate office is determined by each state, and while some offices are housed in state departments of agriculture, others are also tasked with extension and outreach. Regardless of differing structures, prominent in each state is the task of overseeing the state's weather observation sites, including monitoring the compilation and quality control of climate records. Most importantly, the state climatologists' role includes making these records available and accessible to the public. Oftentimes this information is displayed in some format, including text and graphical representations, on a state climate office website, or transferred to a regional climate center or extension climatologist for dissemination via other outlets, such as presentations, personal communications, or hard copy handouts.

In this chapter, a brief overview of research involving communication of climate science information to the agricultural sector in the North Central Region will be presented. First, I will outline theories regarding the roles of science and public engagement in addressing societal problems. Then I will discuss climate change as an environmental and human risk. I will continue by outlining the risks of climate specifically associated with agriculture, and

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opportunities for climate science to assist agriculture in adapting to and mitigating potential risks. Observations will be presented from interviews (N=13) and surveys (N=19) with state and extension climatologists in the North Central Region of the United States. Conclusion and discussion will highlight barriers to effectively connecting climate science to agricultural impacts, including hazard mitigation and risk management.

1.1 Science or Service?

In the early 20th century, John Dewey and Walter Lippman famously debated about the role of public input in developing policy for the democratic society. By definition the appropriate advancement of policy in a democratic government framework required public citizen opinion, Dewey declared, and this input is necessary for the democracy to function as established. On the other hand, society was changing so rapidly, both alleviating and creating complex social problems by advancements of technology; Lippman argued that the role of public citizen input was becoming less important in modern society. As a result, Lippman stated that policy questions should be approached by an educated group of expert leaders, while Dewey maintained that democratic policy decisions require active consideration of all citizen input.

Society was indeed changing in the early 20th century. The establishment of the railroad system, phonograph communication technologies, food preservation advances such as refrigeration, and other important inventions seemingly made life better and brought people closer together. However, already at this time our ancestors were noticing problems still encountered today, such as pollution and resource depletion. In the present year 2013, society is continually advancing to accommodate new technologies, such as wireless communications, global commerce, and genetically modified organisms—to name a few—and social problems are once again being alleviated and created in response to these new influences in life. Perhaps not surprisingly, policy development in our democratic society still grapples with the revolving question of who makes the decisions about how to deal with and respond to these problems: all capable citizens, including public participants, or a group of informed experts?

As to be expected, this dichotomy is still being addressed and debated today. Dan Kahan (2006) and Cass Sunstein (2005) have continued debating in recent years the roles of citizen and expert input in scientific consensus and subsequent policy development. Kahan's (2006) group has argued for the "cultural cognition of scientific consensus," stating that "cultural worldviews permeate all of the mechanisms through which individuals apprehend risk, including their emotional appraisals of putatively dangerous activities, their comprehension and retention of empirical information, and their disposition to trust competing sources of risk information" (p. 1072). On the other hand, Sunstein asserts that a cost-benefit analysis conducted by experts is important to separate irrational public fears from important public values, allowing for less subjective and therefore more democratic policy suggestions.

Potential hazard and risk is an important consideration in almost all aspects of scientific research and subsequent public policy development. To a large extent, scientific endeavors are pursued to address and solve queries or problems whose solution may directly or indirectly benefit the social world. As a result, one could argue that all scientists are public servants in the sense that the work they conduct is directly relative to real-world risks and impacts faced in a modern society.

The definition of risk, however, is up for debate itself. Risk is often defined as "the chance of injury, damage, or loss," according to Webster's dictionary (as cited in Slovic, 1999,

p. 690). However, there is a multitude of social science research that argues that risk itself is inherently subjective (Otway, 1992; Pidgeon, Hood, Jones, Turner & Gibson, 1992; Slovic, 1999; Wynne, 1992). Slovic (1999) argues that "human beings have invented the concept risk to help them understand and cope with the dangers and uncertainties of life" (p. 690). Although we understand that hazards and risks are real in themselves, there may actually be no such thing as "objective risk." Risks assessments often entail subjective judgments, which themselves are modulated by complex social and cultural vantage points.

1.2 Climate as Risk

For those of us with connections to the social world, we may have noticed the increasing news concerning what is commonly referred to as climate change. Even for those with little or no connection to the news, they may have noticed a similar phenomenon in terms of increasingly extreme weather events and climate conditions. One could argue that changing climate is one of the most impending social and environmental concerns of modern times.

The Intergovernmental Panel on Climate Change (IPCC), for example, has emphasized that because agriculture is particularly sensitive to climate variability, societies must develop more resilient and productive agriculture management systems (Field et al., 2007). To highlight the urgent need for members of the public to understand climate change science, the United States Global Change Research Program (USGCRP) released in April, 2012 a 10-year strategic plan containing four key goals to accomplish by the year 2022. Two of these goals are directly relevant to a citizen's capacity to comprehend climate science information:

> (1) Conduct Sustained Assessments: Build a sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities.
> (2) Communicate and Educate: Broaden public understanding of global change and support the development of a scientific workforce skilled in Earth-system sciences. (USGCRP, 2012)

It therefore has become evident that to appropriately address human responses to global climate change, social scientists must consider how the current scientific consensus information on climate is presented, communicated, and diffused to the public.

Tom Armstrong, the Executive Director of the USGCRP said,

> It is no longer enough to study the isolated physical, chemical, and biological factors affecting global change; advanced computing technologies and methods now allow us to integrate insights from those disciplines and add important information from the ecological, social, and economic sciences. This new capacity will deepen our understanding of global change processes and help planners in realms as diverse as storm water management, agriculture, and natural resources management. (USGCRP, 2012)

The United States National Climate Assessment Federal Advisory Committee's Draft Climate Assessment Report states that disruptions to agricultural production are projected to increase, causing negative impacts to most crop and livestock systems by mid-century. The rate at which agriculture adapts to climate change will be important as critical thresholds in production systems are reached, impacting global food security (Walthall et al., 2012). An increase in extreme weather events in the last decade suggests connections to a changing climate (Coumou & Rahmstorf, 2012), matching IPCC projections of "more frequent and more intense extreme weather" (World Meteorological Organization, 2011, p. 2).

The Iowa Climate Change Impacts Committee released a report to the Governor and the Iowa General Assembly titled "Climate Change Impacts on Iowa 2010," in which they concluded, among other things, that Iowa has experienced an increase in extreme spring-time precipitation events (1.25 inches), an increase in frost-free days, an increase in summer dew points, and in fall soil temperatures. Throughout this time, agricultural yield have increased. According to the report,

> Recent weather events and climatic trends are stressing agriculturally related resources. Increased rainfall, and frequency of much heavier-than-normal rainfall events, result in disproportionately negative impacts on soil and water resources and on crop production. Climate extremes, not the averages, frequently control productivity of crops and livestock. (Iowa Climate Change Impacts Committee, 2010, p. 17)

Clearly, climate change has been and will continue to influence environmental risks and hazards. While the extent to which these risks will be realized in the future is currently up for debate, and largely influenced by individual beliefs and social, cultural, and political contexts, it is challenging to deny that climate's influence on agriculture should not be addressed. As a result, it is necessary to further understand how climate will impact agriculture.

1.3 Climate and Agriculture

The North Central Region of the United States encompasses the region commonly referred to as the "Corn Belt" which currently produces a large portion of corn and soybeans to provide local and global supplies. These valuable commodity products are utilized for a large number of outputs, including food, oils, soy-products, fed to animals, silage used for bedding, ethanol, and many other valuable commodities. United States agriculture produces around $300 billion worth of commodities a year. Because agricultural production is dependent on environmental variables such as weather and climate, the United States' National Weather Service is an important resource for the agriculture industry.

Weather observations collected at sites within each state also are fed back to the National Weather Service (NWS), which is a component of the National Oceanic and Atmospheric Administration (NOAA), an Operating Unit of the U.S. Department of Commerce. This information helps inform models that are publicly available through the National Weather Service, such as Climate Outlooks, Seasonal Drought Outlooks, Soil Moisture Forecasts, and the Drought Monitor. Subsequently, the data gained from these observations become available to private weather service companies, who in turn customize it and provide location-specific information to multiple industries, including components of the agriculture sector. In contrast to the public information available by NOAA, which provides seasonal forecasts for the vast spatial region of the whole United States, the forecasts provided by private services are highly personalized and much more spatially precise, offering the public involved with the agriculture sector more localized weather information to guide in them in their various management decisions, from seed selection and population density to dry-down and marketing.

One could ponder the benefits of NOAA producing publicly available, seasonal forecasts with more refined spatial precision, but the lack of funding and other limitations prohibit them from doing so. One notable limitation results from the transfer in 1996 of NWS Agriculture Weather Services to the Private Meteorological Sector as a result of a budget decision on the Commerce Appropriations bill. Since 1890, when the U.S. Congress established the Weather Bureau as an agency of the Department of Agriculture, which eventually became the National Weather Service, the United States government had been providing free and publicly available weather and climate information to the citizens. Much of this information was specifically targeted for application to the agriculture sector. After the privatization of agriculture weather services in 1996, interested citizens have been pointed to a directory of private agriculture weather providers available on the NWS website at http://www.nws.noaa.gov/im/.

Currently, the most widely-accessed source of weather and climate information is a private service called DTN, formerly known as Data Transmission Network, based in Omaha, Nebraska. This company also delivers commodity prices, market information, and agricultural news to over 120,000 unique subscribers. In 2007, DTN purchased from Time Warner *The Progressive Farmer*, an agricultural-oriented magazine reaching approximately 650,000 homes. As previously stated, DTN's weather information is location-specific, and much of the weather forecasting is focused on days or a week into the future, rather than months or seasons.

The most reliable and available seasonal forecasts at the state and climate region within state scales are provided by state climatologists working in conjunction with state and regional climate offices. However, this information is generally not displayed in a consistent or readily-available format in most states. It is often challenging to navigate the websites of state climate offices in search of specific climate information, a task most citizens and particularly farmers are reluctant to perform. To assist the USGCRP's goals in broadening public understanding of global change, it will be important to understand how scientific climate information is communicated from climatologists through various formats and channels and ultimately received by the public, particularly agricultural producers. Specifically, to ensure the productivity and resilience of grain cropping systems in the North Central Region of the United States amid increasingly uncertain environmental variables, it will be beneficial to concentrate on that region of the country.

1.4 Relating Science to Risk

The general public has a skewed conception of science and its role in knowledge and policy development. The emphasis in the scientific method on uncertainties, particularly in atmospheric and other modeling-based sciences, is misinterpreted by the public. When the average citizen thinks about and tries to understand science, they wonder what question it is attempting to address. For instance, how will this science make my life better? In other words, they are attempting to relate science to risks in their life: "Learning processes, or acceptance of new information, are seldom based on concepts of uncertainties or proof, but on risk and risk management" (McBean & Hengeveld, 2000, p. 13). Scientists, on the other hand, embrace the discussion of uncertainties in the continuous advancement of scientific debate.

The IPCC recognizes three scales of uncertainty.

(1) Qualitative uncertainty represents level of understanding, including the amount of scientific evidence and agreement amongst scientists.
(2) Quantitative uncertainty refers to the confidence of a certain finding in being correct.
(3) Probabilistic uncertainty acknowledges the likelihood of the occurrence of a certain event.

Interestingly, each of the three IPCC Working Groups differentially approached the concept of uncertainty, because of necessary differences of methodological approaches and subject matters between scientific disciplines (Swart, Bernstein, Ha-Duong & Petersen, 2009). The inconsistencies of how uncertainty is addressed and perceived is a large barrier in the public's interpretation and reception of scientific findings of the IPCC report (Jonassen & Pielke, 2011).

The complex social, cultural, and political contexts, as well as general perceptions of science, that influence that ability of public weather and climate data users to understand currently available science is of utmost importance. As individuals tasked with providing scientific knowledge to the public, state and extension climatologists have a unique role to assist farmers and the agricultural sector access climate information for use in developing agricultural management portfolios to adapt to and mitigate environmental risks in order to remain resilient and profitable. Because of this, it is necessary to understand how climatologists currently communicate information, including perceptions of their roles as scientists, and opportunities for more effective climate science communication. To do so, I further examine the following research question: How do climatologists in the North Central Region perceive their role in communicating climate science to agriculture?

2. METHODOLOGY

State and extension climatologists in the 12 states of the North Central Region (NRC) were contacted from a purposeful sample and asked to participate in the project. In-person interviews (N=13) and surveys (N=19) were conducted to investigate how climatologists in this region currently communicate to the agriculture sector, as well as opportunities and barriers for more effective climate science communication.

Interviews were transcribed and analyzed by two independent coders utilizing a qualitative analysis code book. Key words were determined to investigate eight themes: (1) objectivity, (2) agricultural management relevance, (3) agricultural economics and marketing, (4) agricultural decision timing, (5) location relevance, (6) format, (7) engagement, and (8) conservation management relevance. Cohen's Kappa was calculated to ensure inter-rater reliability, with all values >.866.

Frequencies were tallied for each theme mentioned to determine location on a spectrum of climate science communication from objective, to relevant, and then engaged (Wilke & Wright Morton, (under review); adapted from Fischoff (1995)). Pielke's (2007) idealized roles of science in society theoretical framework was also applied to ensure reliability of frequency results. It was determined that in each case, the majority of climatologists are focused on providing objective and accurate information, while relatively fewer climatologists acknowledge the communication techniques of framing scientific information as relevant and engaging the audience to build a trusted communication atmosphere.

3. RESULTS

> "We have a research role, and that's trying to understand temporal and spatial trends of climate within the state and . . . also projected climate in the future—that's been a hot topic in the last decade or so. And we also have an educational mission, and that is to try and incorporate pieces of what we

> do in educational opportunities for students but also in terms of public outreach and educate the public on climate science and climate-related issues" (1204200901, p. 1).[1]

Climatologists provide weather and climate science information to public data users in their state. In the North Central Region (NCR) of the United States, this encompasses a large group of farmers and other stakeholders in the agricultural sector. Climatologists are therefore tasked with actively communicating climate science to agriculture because the agricultural audience constitutes a significant portion of NCR climatologists' constituents.

The main recognized role of the climatologists is that of scientist—to develop and test research questions utilizing the scientific method. Other roles involve data and technological management, including maintaining weather observation equipment. Climatologists often interact with one another and regional climate centers to exchange information. Public service is also a role recognized by climatologists within the land-grant institutions, encompassing the presentation and communication of scientific information to the public.

Many of the state climate offices in the NCR interact extensively with agriculture. However, this varies somewhat by state. For instance, in Michigan there is a large fruit sector, which requires different types of information than typical in the Corn Belt. In the far western part of the NCR, irrigation agriculture also requires different types of information than rain-fed regions. Information for agricultural livestock producers is also important in dairy regions such as Wisconsin.

Climatologists largely recognize that there are gaps in the ability to collect information. When asked about what information would be helpful to the agriculture sector but is not currently available, common responses included soil moisture, solar radiation, and evapotranspiration. Communication challenges are also recognized, and many climatologists noted that even though science is advancing, it does not mean that the public realizes what is available or will apply it in decision making.

There is recognition that farmers do utilize weather and climate information; however, there are social, cultural, and political factors that moderate application of currently available scientific knowledge. As has been indicated by the Intergovernmental Panel on Climate Change, the National Climate Assessment Federal Advisory Committee's Draft Climate Assessment Report, and the Iowa Climate Change Impacts Committee, scientists have stated the climate is an environmental risk. These reports also suggest that agriculture is particularly sensitive to climate change and variability because of its reliance on atmospheric and terrestrial interactions.

While agriculture is at risk to extreme weather events and climate variability, there is recognition that science can assist individual and collective decision making to help agriculture adapt to changes and remain resilient and profitable (Likens, 2010). As individuals tasked with creating and communicating climate-related science, climatologists are at the forefront of helping agriculture and society address potential problems associated with increasingly unpredictable environmental risks. Climatologists are key actors in helping farmers understand environmental uncertainties that influence agricultural production. Therefore, climatologists must embrace roles beyond the production of scientific information to also encompass the translation and dissemination of this information to public audiences.

Fischoff's (1995) seven stages of uncertain risk communication provide a valuable framework to understand how climate-related risks are communicated by climatologists. As

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[1] Quotations are selected from interviews conducted between March and May 2012, see Wilke (2013) for details.

main themes emerged during the interview analysis, we found it helpful to collapse these stages into three main elements (see Wilke & Wright Morton, under review). Our findings indicate that the majority of climatologists are focused on the first element, objective and accurate. However, social and decision theory suggests that it is also necessary to embrace communication techniques of the second and third elements by providing information that is relevant and important and communicating it in a way in which the audience is engaged and the messenger is trusted. By engaging farmers in citizen science programs such as the Community Collaborative Rain, Hail, and Snow Network, as well as providing information that is agriculture- and location- specific, climatologists may more effectively communicate to farmers and other stakeholders in the agricultural sector.

Pielke's (2007) four idealized roles of science in society are also an important framework to understand climatologists perceived roles as scientists. Results indicate that the majority of climatologists are focused on the role of producing science as pure scientists. However, some climatologists did recognize the need to arbitrate information when requested. A few climatologists mentioned the need to communicate information to society, in line with the role of honest broker. These findings indicate the importance of a two-pronged approach to climate science communication for agriculture, in which science is first produced and then actively disseminated to the needs of farmers and other stakeholders. Further, the communication of current knowledge should be framed in terms of risk management and hazard mitigation as a positive option to benefit society and public health.

Having demonstrated these two findings, there is one important further recommendation to address the climate science communication gap. The phrase "global warming" was often connected with climate science, and has since been phased out as a misappropriation because warming is just one factor associated with global change. However, when we are considering climate science, the phrase "climate change" may influence the audiences' willingness and ability to comprehend and accept scientific information. It is important to remember that by definition, climate is always changing. Climate change, then, often evokes perceptions of human-induced changes. However, climate science recognizes all changes of weather over time. As a result, it may be helpful when communicating climate science for climatologists to simply refer to "climate."

3. 1 Implications

As public servants of the land-grant universities, climatologists largely perceive their roles to remain objective providers of scientific information. However, there is much evidence in the decision and social sciences that indicate scientists' roles encompass both production and communication of research to assist individual and collective decision makers in applying modern knowledge to address social problems. Late agricultural economist and extension scholar James T. Bonnen (1996, 1998) argued for the urgent need of land-grant institutions to evolve in order to meet the needs of a changing and modernizing society. To protect the integrity of the land-grant mission, he outlined seven potential risks of university intervention in society. Interestingly, these risks more or less follow the framework outlined by Fischoff (1995), from letting society decide how to implement science in policy development, to suggesting or advocating certain societal responses on account of scientific consensus.

Dr. Bonnen (1996) recognized the extreme level of risk intertwined with the land-grant institutions, and their affiliated employees and scientists, advocating societal and public policy response to matters of scientific consensus. As a result, he suggests that the highest level of risk involves advocating for certain societal responses to scientific consensus, specifically public policy development. However, it is argued that exceptions include "situations in which there was such great consensus in the community of the program goals and actions that the risk associated with public advocacy was nil" (Bonnen, 1998, p. 65). Further, these situations occur when a social consensus is so outstanding that any potential pushbacks to advocacy are nullified.

As a boundary between scientific knowledge and public data users, land-grant institutions have tremendous potential to assist society in adapting to and mitigating environmental risks associated with weather and climate. However, institutional structures, funding mechanisms, traditions, and reward and review systems hinder the ability of universities to evolve the interface between society and science (Whitmer et al., 2010). It will be necessary to change how scientists are trained and rewarded to integrate science with society and policy (Pouyat et al., 2010).

4. CONCLUSION

On November 19, 2012, one hundred and eight scientists and researchers from twenty seven colleges and universities in the state of Iowa released the Iowa Climate Statement in response to the drought of 2012, declaring "we have confidence in recent findings that climate change is real and having an impact on the economy and natural resources of Iowa. We feel that it is important for citizens of Iowa to understand its implications" ("Iowa Climate Statement," 2012). This is one example in which climate science consensus has been directly connected to real-world impacts and risks. As the risks of increasingly variable climate patterns and extreme weather conditions become more certain to the scientific community, it is imperative that connections between scientific consensus and real-world impacts be addressed. In doing so, the communication of climate information to agricultural audiences will become much more effective, allowing for management operations to adapt their long-term portfolios to remain productive and resilient, while assisting in the mitigation of variable climate conditions.

There are many examples of civil society demanding that individual and collective decision makers take a stance on climate. For instance, On February 17, 2013 approximately 40,000 people marched to the White House in Washington, D.C. to demand that President Obama move "Forward on Climate." This event was held to demonstrate that citizens are concerned about the current state of energy policy in the country, and believe that appropriate policies need to be developed to address the environmental hazards associated with increasing extreme weather events and unpredictable climate conditions. The event was very timely, as President Obama declared in his State of the Union address, "We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations." This statement strongly echoed the conclusions of United States Secretary of Energy Steven Chu (2013), who declared in a speech to Iowa State University, "The oil and gas industries have received subsidies for the past 100 plus years—it is time to level the playing field." Secretary Chu concluded, "I think we have a moral responsibility. . . . The most innocent victims in climate change are the poorest who never contribute anything to this and those yet to be born" (Chu, 2013).

Clearly, climate science is urgently needed to assist the public and policy makers in developing individual and collective decisions regarding climate. Regardless of one's personal beliefs regarding future global change, this example demonstrates a situation in which the engagement of scientists with society is increasingly necessary for all stakeholders to potentially benefit. By remaining in the idealized role of pure scientist, climatologists are not allowing the full beneficial potential of their knowledge accumulation to be realized. It will become more important for climatologists to recognize their roles as experts in democratic society and embrace the application of their science for the betterment of society. By doing so, they will achieve the more modern balance of scientific progression between opportunity and needs.

However, as long as the topic of climate change remains a controversial political issue (Moser, 2010) and institutional structures hinder the ability of scientists to connect scientific discoveries to societal impacts (Whitmer et al., 2010), climatologists will remain feeling "[k]ind of frustrated that you feel like you can't really say what you want to say" (1205010503, p. 8). Further, as public servants of land-grant institutions, climatologists will continue refraining from connecting science to society, as well as communicating with popular public outlets to avoid "issues with my job from actually just being misquoted" (1205010503, p. 8). One climatologist even stated that "[g]uidance, I think, is then provided, and should be provided, to any agency or any individual, anyone who is going to make a public comment" (1206061201, p. 3)

One could argue that the climate science field greatly harmed their credibility by advocating one response to future problems: to reduce fossil carbon use. Had the scientific leaders in advocating policy response to current climate science consensus approached the issue slowly and offered potential outcomes and all potential responses, communicating this information to the public, and then stepping back and letting them decide, perhaps outcomes may have been more rapid and productive. Sometimes people know what the right thing is to do, but most people do not appreciate being told what to do, and will sometimes do the exact opposite. This is particularly evident in historically conservative social groups, such as farmers.

There is a large body of evidence to indicate that human forcings beyond carbon dioxide, particularly land cover and land use changes, are influencing atmospheric-terrestrial interactions that affect both local and global weather and climate patterns (DeFries, Foley, & Asner, 2004; Diffenbaugh, 2009; Foley, Costa, Delire, Ramankutty, & Snyder, 2003; Foley et al., 2005; McAlpine et al., 2010; Pielke et al., 2009, 2011; Twine, Kucharik, & Foley, 2004). A recent study using satellite photos demonstrated that from 2006 to 2011, 1.3 million acres of grassland were converted to corn and soybeans in the northern Great Plains (Wright & Wimberly, 2013). This is just one example of relevant interactions between climate and agriculture that scientists could communicate to public data users. Another potential avenue to make climate information important and relevant is by exploring the frame of public health (Dilling & Moser, 2006; Maibach, Roser-Renouf,& Leiserowitz, 2008; Moser, 2006; Nisbet, 2009) to avoid complications of emphasizing fear as a means to motivate individual action (O'Neill & Nicholson-Cole, 2009). By focusing on the potential human health benefits of adapting to and mitigating a wide range of atmospheric-terrestrial interaction influences, climatologists may more effectively reach broader audiences of the public.

In closing, I would like to briefly return to the topic of public engagement in science, democracy, and public health. This paper has suggested that climate is a risk to the agricultural sector, which influences the production of food and environmental wellbeing. Results indicate that climatologists could benefit from actively communicating scientific information and enlarging all potential impacts of current scientific consensus for public data users to make individual and collective decisions, as well as appropriate public policy. In this process, it is of utmost importance to consider the public's input on issues dealing with individual value systems and beliefs, such as concepts like "ecosystem health." As society increasingly demands that the natural environment provide services which support human health, such as clean air and water, science must actively address these concerns in developing research methodologies to inform decision making and public policy. A scientific communication strategy that encompasses hazard mitigation and risk management will help society remain food secure and healthy for generations to come, regardless of uncertain future weather extremes and climate variability.

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REFERENCES

Bonnen, J. T. (1996*). Land grant universities are changing*. Staff Paper 96–100. Unpublished manuscript, Michigan State University, East Lansing, MI.

Bonnen, J. T. (1998). The land grant idea and the evolving outreach university. In R. M. Lerner and L. A. Simon (Eds.), *University-community collaboration for the twenty-first century: Outreach to scholarship to youth and families* (pp. 463-480). New York, NY: Garland.

Chu, S. (2013, February 12). Solving the energy and climate change challenge. Lecture conducted from Iowa State University, Ames, IA.

Cuomou, D., & Rahmstorf, S. (2012). A decade of weather extremes. *Nature Climate Change, 2,* 491–496.

DeFries, R., Foley, J., & Asner, G. (2004). Land-use choices: Balancing human needs and ecosystem function. *Frontiers in Ecology and the Environment, 2*(5), 249–257.

Diffenbaugh, N. (2009). Influence of modern land cover on the climate of the United States. *Climate Dynamics, 53*, 945–958.

Dilling, L., & Moser, S.C. (2006). Introduction. In S.C. Moser & L. Dilling (Eds.), *Creating a climate for change: Communicating climate change and facilitating social change* (pp. 1–27). Cambridge: Cambridge University Press.

Field, C., Mortsch, L., Brklacich, M., Forbes, D., Kovacs, P., Patz, J., . . . & Scott, M. (2007). North America. In . M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, & C.E. Hanson (Eds.), *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 617–652). Cambridge: Cambridge University Press.

Fischhoff, B. (1995). Risk perception and communication unplugged: Twenty years of progress. *Risk Analysis, 15*, 137–45.

Foley, J., Costa, M., Delire, C., Ramankutty, N., & Snyder, P. (2003). Green surprise? How terrestrial ecosystems could affect earth's climate. *Frontiers in Ecology and the Environment, 1*(1), 38–44.

Foley, J., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, S.F.,… Snyder, P.K. (2005). Global consequences of land use. *Science, 309*, 570–574.

Hardaker, J. B. (2004) *Coping with risk in agriculture.* Wallingford, Oxfordshire: CABI Pub.

Iowa climate statement: The drought of 2012. (2012, November 19). Retrieved from http://www.cgrer.uiowa.edu/images/main_slideshow/ICS_drought2012FINAL.pdf

Iowa Climate Change Impacts Committee. (2010). Climate change impacts on Iowa 2010: Report to the governor and the Iowa General Assembly. Retrieved from http://climate.engineering.iastate.edu/Document/Olson_Amend_Report.pdf

Jonassen, R., & Pielke, R., Jr. (2011). Improving conveyance of uncertainties in the findings of the IPCC. *Climatic Change, 108,* 745–753.

Kahan, D. M. (2006). Fear of democracy: A cultural evaluation of Sunstein on risk. *Faculty Scholarship Series Paper 104,* Yale Law School, Yale University, New Haven, CT. Retrieved from http://digitalcommons.law.yale.edu/fss_papers/104/

Likens, G. (2010). The role of science in decision-making: Does evidence-based science drive environmental policy? *Frontiers in Ecology and the Environment, 8*(6), e1–e9.

Maibach, E.W., Roser-Renouf, C., & Leiserowitz A. (2008). Communication and marketing as climate change intervention assets: A public health perspective. *American Journal of Preventive Medicine, 35*, 488–500.

McAlpine, C.A., Laurance, W. F., Ryan, J. G., Seabrook, L., Syktus, J.I., Etter, A. E., . . . & Pielke, R. A., Sr. (2010). More than CO2: A broader picture for managing climate change and variability to avoid ecosystem collapse. *Current Opinion in Environmental Sustainability, 2*, 334–336.

McBean, G. A., & Hengeveld, H. G. (2000). Communicating the science of climate change: A mutural challenge for scientists and educators. *Canadian Journal of Environmental Education, 5*, 9–25.

Moser, S. C. (2010). Communicating climate change: History, challenges, process and future directions. *WIREs Climate Change, 1*, 1–27.

Nisbet, M. (2009). Communicating climate change: Why frames matter for public engagement. *Environment: Science and Policy for Sustainable Development, 51*(2), 12–23.

O'Neil, S. & Nicholson-Cole, S. (2009). "Fear won't do it": Promoting positive engagement with climate change through visual and iconic representations. *Science Communication, 30*(3), 355–379.

Otway, H. (1992). Public wisdom, expert fallibility: Toward a contextual theory of risk. In S. Krimsky & D. Golding (Eds.), *Social theories of risk* (pp. 215–228). Westport, CT: Praeger.

Pidgeon, N., Hood, C., Jones, D., Turner, B., & Gibson, R. (1992). Risk Perception. In Royal Society Study Group (Ed.), *Risk: Analysis, Perception and Management* (pp. 89-134). London: The Royal Society

Pidgeon, N., & Fischhoff, B. (2011). The role of social and decision sciences in communicating uncertain climate risks. *Nature Climate Change*, *1*(1), 35–41.

Pielke, R.A., Jr. (2007). *The honest broker: Making sense of science in policy and politics.* Cambridge: Cambridge University Press.

Pielke, R. A., Sr., Beven, K., Brasseur, G., Calvert, J., Chahine, M., Dickerson, R., . . . & Wood, E. (2009). Climate change: The need to consider human forcings besides greenhouse gases. *Eos, 90*(45), 413.

Pielke, R. A, Sr., Pitman, A., Niyogi, D., Mahmood, R., McAlpine, C., Hossain, F., . . . & de Noblet-Ducoudré, N. (2011). Land use/land cover changes and climate: Modeling analysis and observational evidence. *WIREs Clim Change, 2*, 828–850.

Pouyat, R..V., Weathers, K.C., Hauber, R., Lovett, G.M., Bartuska, A., Christenson, L.,…Lymn, N. (2010). The role of federal agencies in the application of scientific knowledge. *Frontiers in Ecology and the Environment, 8*(6), 322–328.

Slovic, P. (2000). *The perception of risk.* London: Earthscan Publications, Ltd.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis, 19*(4), 689–701.

Swart, R., Bernstein, L., Ha-Duong, M., & Petersen, A. (2009). Agreeing to disagree: Uncertainty management in assessing climate change, impacts and responses by the IPCC. Climatic Change., 92(1-2), 1-29.

Sunstein, C. (2005). *The Laws of fear: Beyond the precautionary principle.* Cambridge: Cambridge University Press.

Twine, T., Kucharik, C., & Foley, J. (2004). Effects of land cover change on the energy and water balance of the Mississippi river basin. *Journal of Hydrometeorology, 5*, 640–655.

United States Global Change Research Program. (2012, April 27). Administration releases 10-year global change strategic plan [Press release]. Retrieved from http://www.globalchange.gov/whats-new/689-new-usgcrp-strategic-plan-for-2012-2021

Walthall, C.L., et al. (2012). *Climate change and agriculture in the United States: Effects and adaptation.* USDA Technical Bulletin 1935. Washington, DC: USDA.

Whitmer, L., Ogden, L., Lawton, J., Sturner, P., Groffman, P., Schneider, L.,…Killilea, M.. (2010). The engaged university: Providing a platform for research that transforms society. *Frontiers in Ecology and the Environment, 8*(6), 314-321.

Wilke, A. K., & Morton, L. W. (2013). Communication climate science: Components for engaging the agricultural audience. Manuscript submitted for publication.

Wright, C., & Wimberly, M. (2013). Recent land use change in the Western Corn Belt threatens grassland and wetlands. *PNAS Early Edition,* 1-6. Retrieved from http://www.pnas.org/content/early/2013/02/13/1215404110.full.pdf

Wynne, B. (1991). Knowledges in context. *Science, Technology and Human Values, 16*(1), 111–121.

Wilke, A. (2013). Climatologists' methods of climate science communication to agriculture in the North Central Region of the United States. Graduate Theses and Dissertations. Paper 13185. http://lib.dr.iastate.edu/etd/13185